Next Generation High Power Dual-Frequency Transmitter For Space Borne and/or Air Borne Doppler Radar Precipitation Measurements

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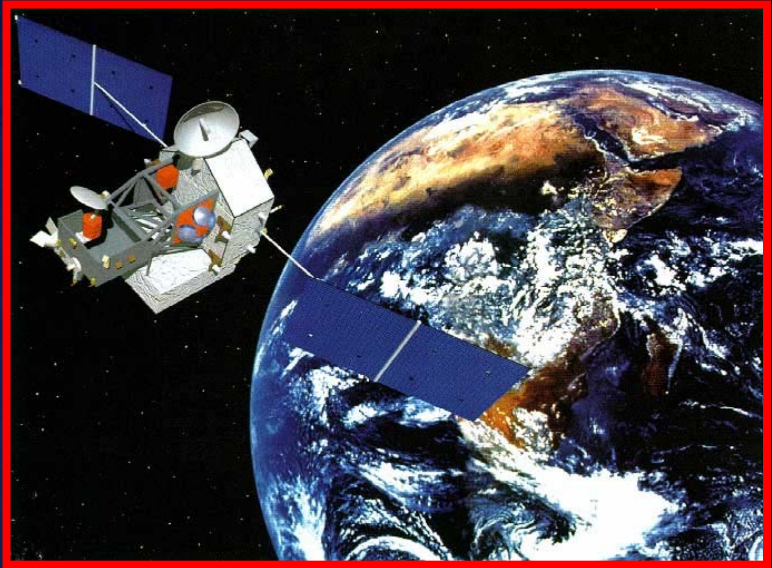
Background

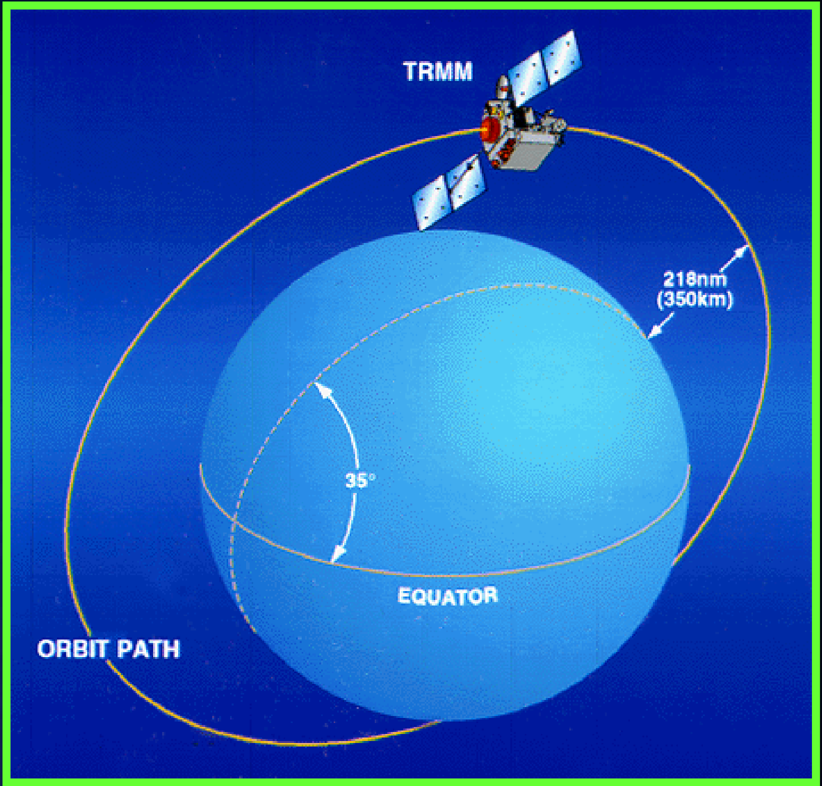
- Tropical Rainfall Measuring Mission: Only current U.S. satellite based precipitation measurement radar, launched in 1997, operates at a single Ku-band frequency of 13.8GHz.

- Computes:
  - intensity, variability, and spatial distribution of rainfall
  - rain type
  - storm depth
  - other essential weather data



TRMM Limitations

- Limited in measurements of precipitation in the hydrologic cycle and accurate rainfall estimations
- Limited view of Earth (ranging from 36° N to 36° S)
- Samples rain relatively infrequently
- Cannot measure frozen precipitation
- Insensitive to light rainfall
- Passes over same location approx. once a day



Global Precipitation Measurement

- Global Precipitation Measurement (GPM): dual-frequency radar system operated at both Ku-band (13.8GHz) and Ka-band (35.6GHz).

- The GPM would require two TWTAs with possibly two antennas.

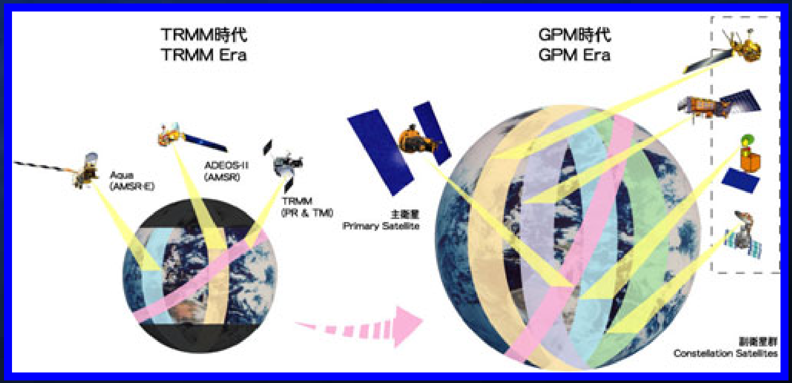
The Core:
- GPM Microwave Imager (GMI)
- Dual Frequency Precipitation Radar (DFPR)

Constellation system
- Max. 8 satellites

GPM Advantages

GPM is designed to account for downfalls of TRMM

- More detailed observations of rainfall processes
- Significantly more accurate rainfall measurements
- Superior estimates of drop size and distribution (dual-frequency)
- Higher latitudes
- More understanding of global hydrological cycle
- Estimate various sizes of precipitation
- Difference between snow and rain
- 3-hour avg. revisit time over 80% of Earth
- Data available within 3 hours of observing

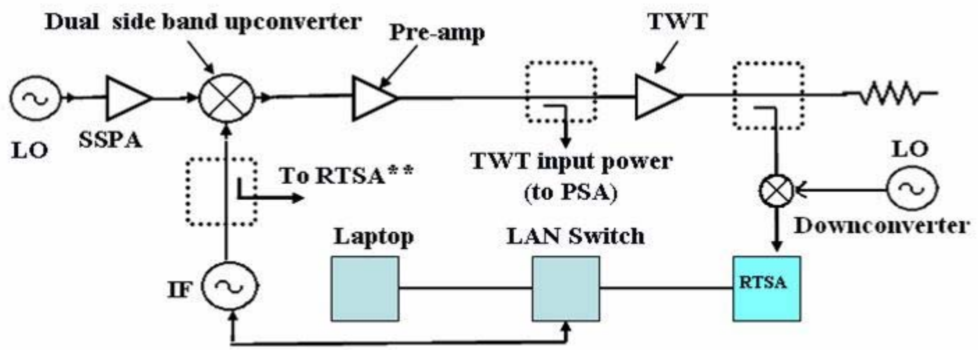


Our Research

- Dr. R. Meneghini at NASA GSFC showed the possibility of an approach using only a single transmitter and smaller antenna.
  - Same increased accuracy
    - pulsed radar system
    - two Ka-band frequencies 7-10% apart
  - Reduces size, mass and electrical power required for the system

- Testing feasibility of operating a single TWTA to amplify pulses at two Ka-band frequencies

Circuit Diagram



** RTSA - Real time spectrum analyzer

- FM modulated pulse (linear FM chirp) at 1.75GHz (IF) mixes with LO signal in dual side band upconverter
- RF output is LO±IF
- RF signals sent through TWT
- Downconverter mixes two RF frequencies with a second LO frequency to obtain two IF frequencies that are within range of RTSA (3GHz max)
- Both IF signals looked at separately using RTSA to compare modulated pulses before and after TWT

Stephen's Work

- Assisted in the collection of data
- Learned how to use more complex functions of analysis equipment for more accurate analysis of data
- Helped narrow the choice of pulse bandwidth and length that are useful in our test setup (RTSA limitation)
- Characterized various circuit components (filters, cables, etc.) and modified the circuit as needed for different types of data collection

Equipment


WARNING
2.4MM ONLY

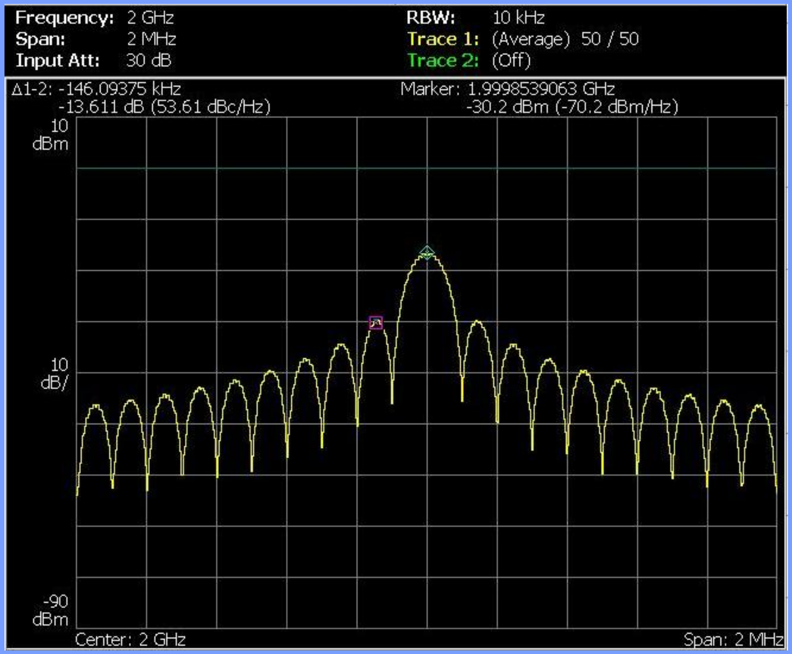

BOEING
Boeing Electron Dynamics Devices, Inc.
TWT Model 999H
Serial Number 102

Stephanie’s Work

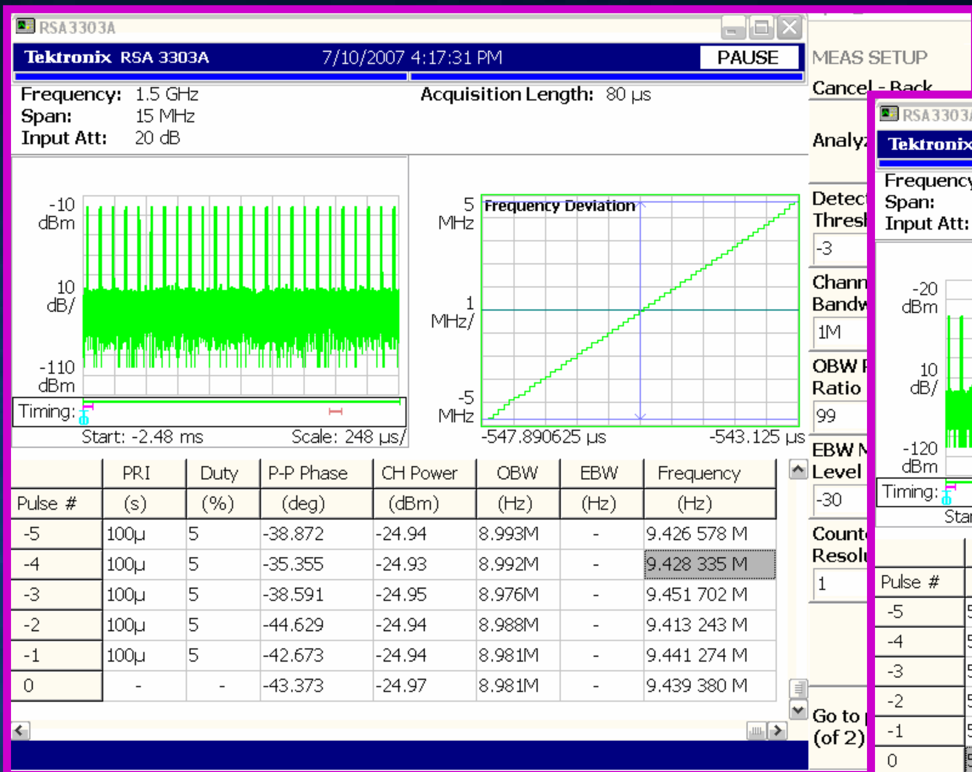
- Assisted in pulse analysis
- Explored applicability of new software for data analysis
  - MATLAB
  - Tektronix
  - Agilent
- PowerPoint movies to demonstrate pulse-to-pulse changes in waveform

Methods of Analyzing Data

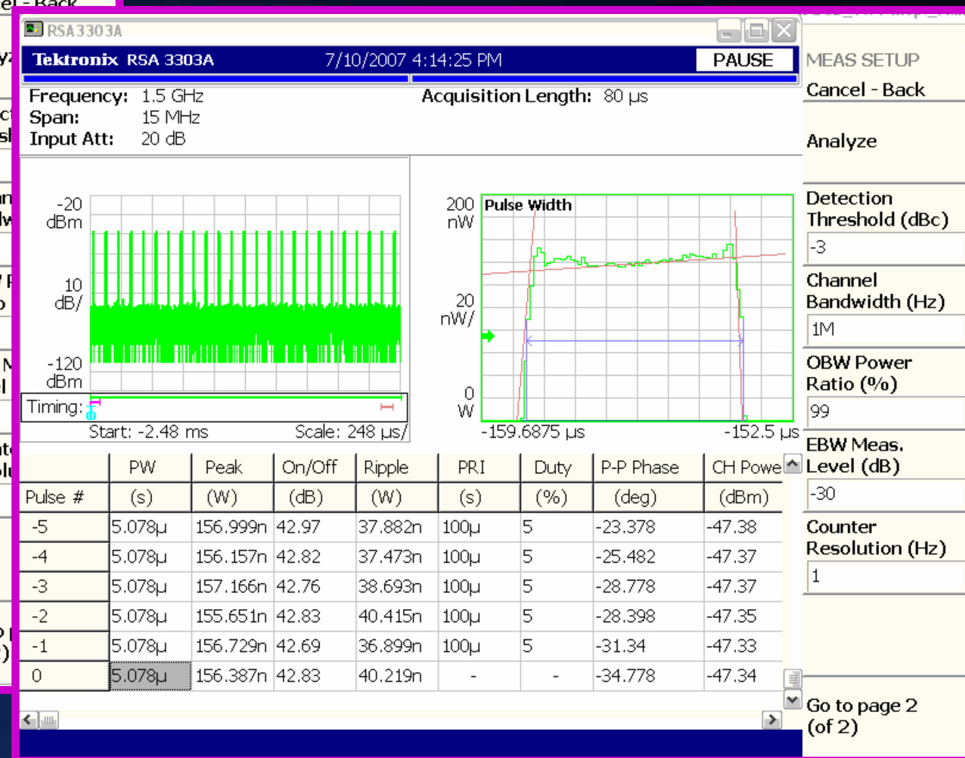
- The Tektronix RTSA offers the method we are using of viewing pulses in the time domain, although it is limited to a pulse bandwidth of 15 MHz in real time
  - Most analysis to date is semi-quantitative, we are looking into methods to enable more detailed quantitative comparisons
- Vector Signal Analysis (VSA) software from Agilent for use with our Performance Spectrum Analyzer (PSA) to observe the modulated signals at Ka-band in the time domain
  - MATLAB Signal Processing Toolbox is a possible analysis tool



Pulse Analysis Results

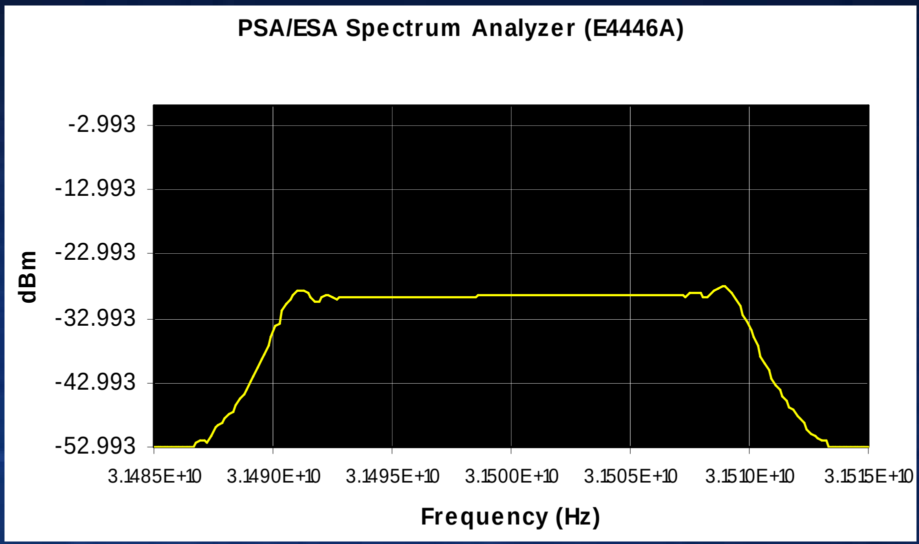


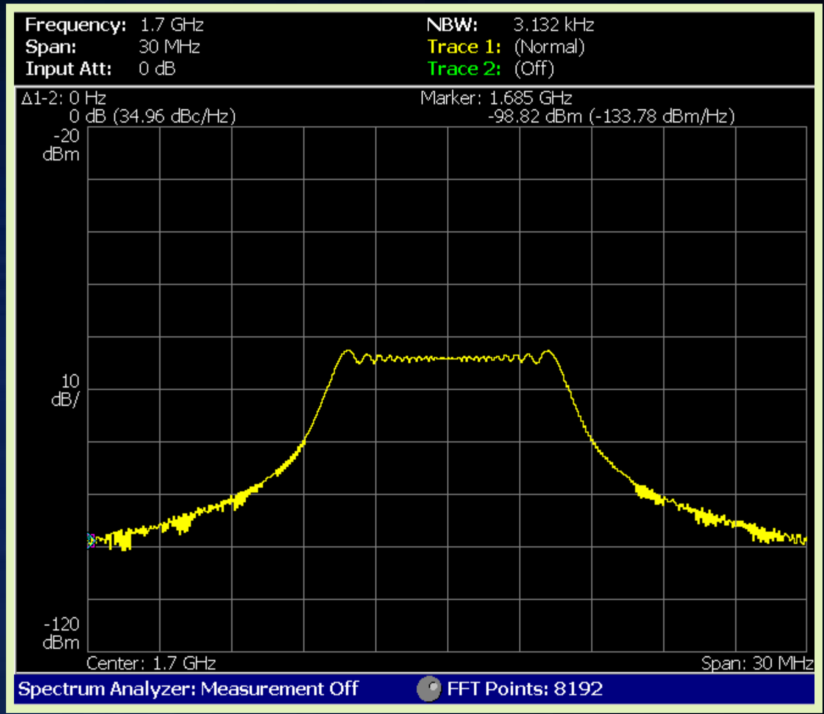
Pulse #	PRI (s)	Duty (%)	P-P Phase (deg)	CH Power (dBm)	OBW (Hz)	EBW (Hz)	Frequency (Hz)
-5	100µ	5	-38.872	-24.94	8.993M	-	9.426 578 M
-4	100µ	5	-35.355	-24.93	8.992M	-	9.428 335 M
-3	100µ	5	-38.591	-24.95	8.976M	-	9.451 702 M
-2	100µ	5	-44.629	-24.94	8.988M	-	9.413 243 M
-1	100µ	5	-42.673	-24.94	8.981M	-	9.441 274 M
0	-	-	-43.373	-24.97	8.981M	-	9.439 380 M



Pulse #	PW (s)	Peak (W)	On/Off (dB)	Ripple (W)	PRI (s)	Duty (%)	P-P Phase (deg)	CH Powe (dBm)
-5	5.078µ	156.999n	42.97	37.882n	100µ	5	-23.378	-47.38
-4	5.078µ	156.157n	42.82	37.473n	100µ	5	-25.482	-47.37
-3	5.078µ	157.166n	42.76	38.693n	100µ	5	-28.778	-47.37
-2	5.078µ	155.651n	42.83	40.415n	100µ	5	-28.398	-47.35
-1	5.078µ	156.729n	42.69	36.899n	100µ	5	-31.34	-47.33
0	5.078µ	156.387n	42.83	40.219n	-	-	-34.778	-47.34

Spectrum Analyzer Results

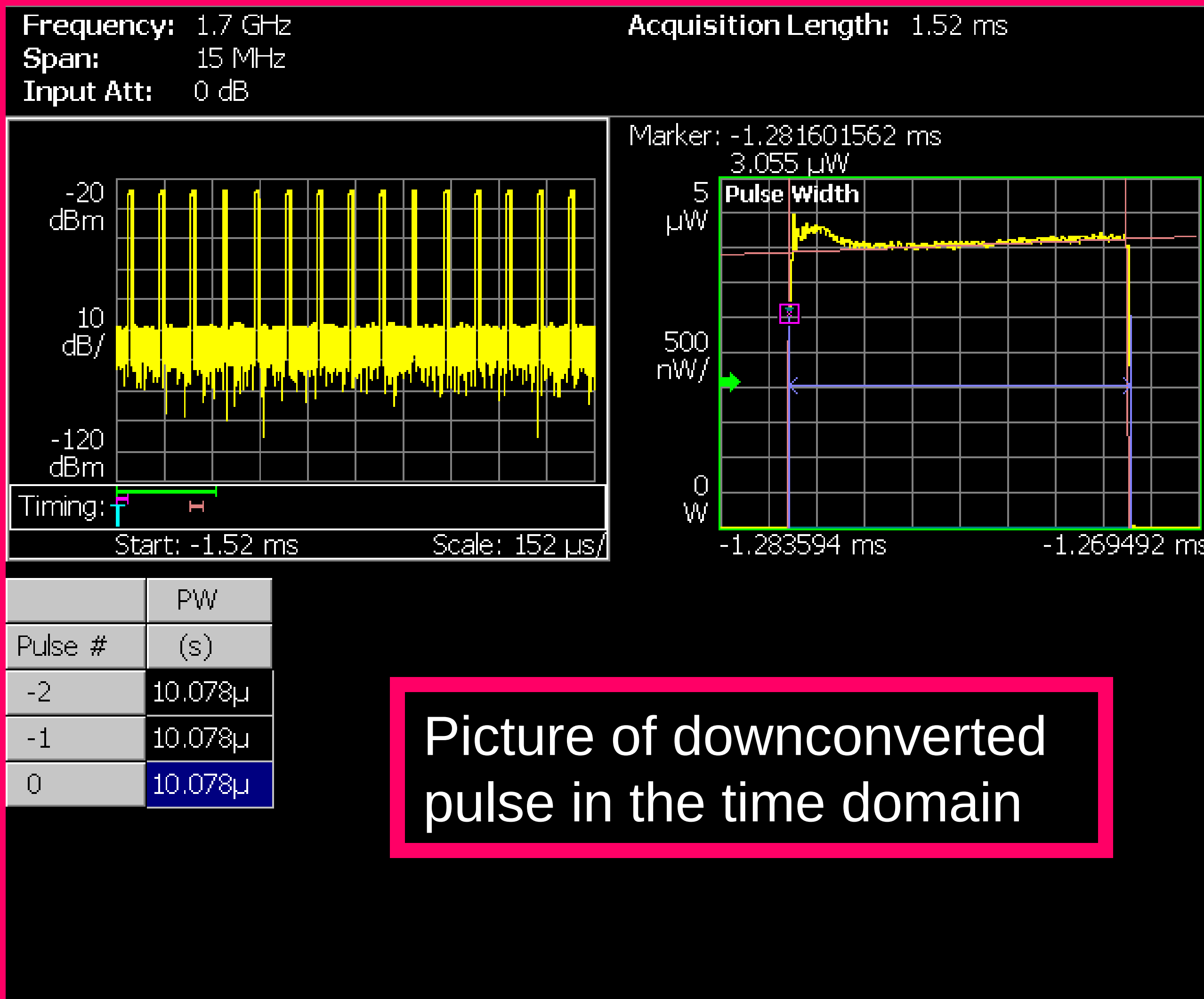




Modulated pulse prior to downconversion in frequency domain

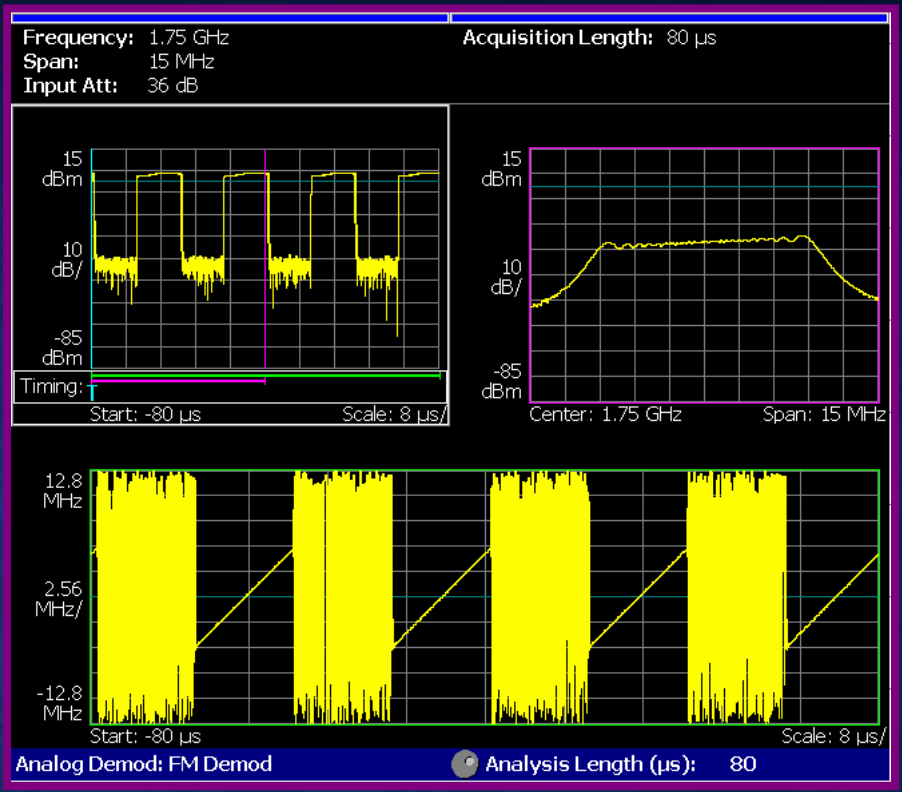
Downconverted pulse in the frequency domain

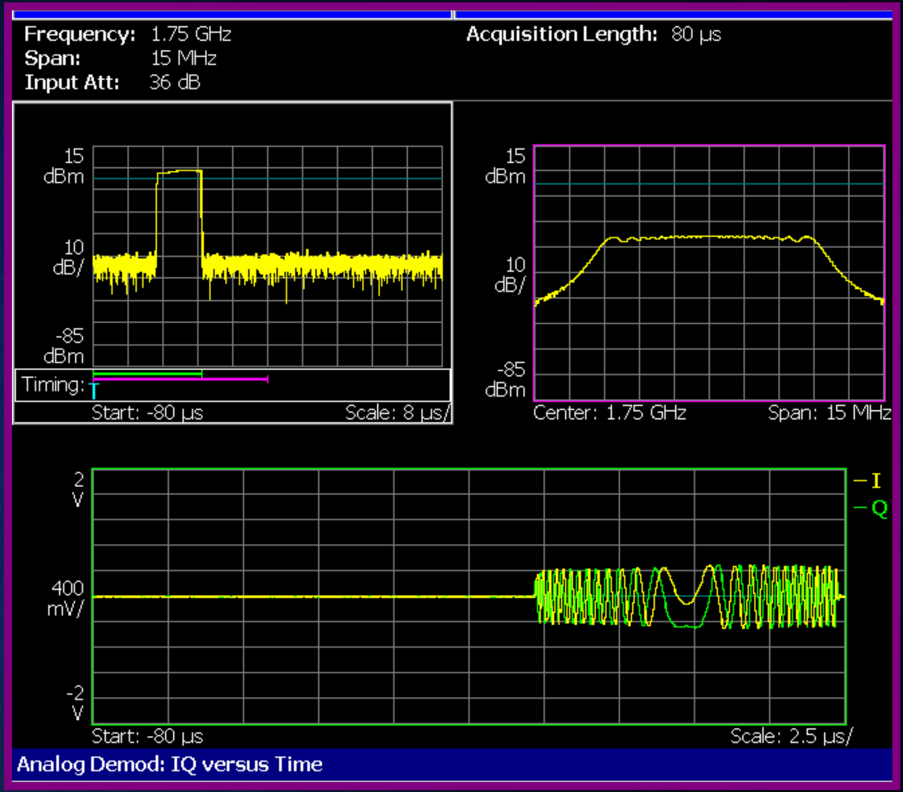
Spectrum Analyzer Results



Picture of downconverted pulse in the time domain

Results





Other RTSA display modes

Current and Future Work

- Current work
  - Investigate effect of TWT phase modulation on CW signal using single frequency
  - Investigate distortion effects of TWT on pulse waveform and phase using single frequency
  - Look into new filtering techniques to minimize intermodulation products
- Possible alternative approach – staggered instead of simultaneous pulses
- Benefits of staggered pulses
  - Full peak power at each frequency
  - Avoid intermodulation products

Current and Future Work

- Refine ability to evaluate radar pulse modulations (FM chirp)
- Compare GRC findings to GSFC calculations
- Improve ways to quantitatively measure pulse characteristics after passing through TWT

References

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